

Kochia prostrata Germplasm Collection Expedition to Kazakhstan

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Abstract—The low stature of ‘Immigrant’ forage kochia (*Kochia prostrata*) limits its use as winter forage and habitat for livestock and wildlife. In October 1999, a germplasm collection trip was undertaken to obtain forage kochia ecotypes that have potential to improve fall and winter forage. The collection area was north of the Aral Sea in the Clay and Sand Desert Steppes of Kazakhstan. Seed samples brought back to the U.S. included 192 forage kochia ecotypes. The desert shrub ecosystems had major components of chenopods. In general, the area was classified as Brown Desert Steppe, Light Chestnut Steppe, Solonetz, or Degraded Solonetz. Most soils in the Clay Desert Steppes had a clay to clay loam subsoil and were generally saline and alkaline. Elevation ranged from 250 to 1,000 feet above sea level. Average annual precipitation was 6 to 9 inches. Average annual air and soil surface temperatures were 41 and 44 degrees Fahrenheit, respectively. On average, forage kochia made up 6 percent of the plant composition on sites in the native steppe where it was present, ranging from 1 to 20 percent. Forage kochia was more prevalent when present on disturbed areas such as abandon fields, homesteads, and roadways, where it comprised 15 to 60 percent of the plant composition. Flow cytometry analysis revealed that 2x, 4x, and 6x ploidy levels of forage kochia were collected.

Introduction

Forage kochia (*Kochia prostrata*) is a valuable semi-shrub for rangeland rehabilitation. Some of its uses include soil stabilization in saline/alkaline semi-arid sites, green strip-ping to help control wildfires, wildlife and livestock forage and cover, and to suppress invasion of annual weeds such as

cheatgrass (*Bromus tectorum*) and halogeton (*Halogeton glomeratus*) (Harrison and others 2000). A 3-year study investigating the adaptability and potential for ‘weedy’ invasiveness of forage kochia was conducted by the United States Department of Agriculture, Agriculture Research Service (USDA-ARS), Forage and Range Research Laboratory (FRRL) in Logan, UT. Harrison and others (2000) reported that forage kochia was widely adapted to the semi-arid and arid ecosystems of the Great Basin Intermountain Region, but was not an aggressive or weedy invader of perennial or closed plant communities.

A forage kochia breeding and genetics program was initiated in 1998 at the USDA-ARS-FRRL in response to increasing interest in forage kochia for fall/winter livestock grazing on privately owned land. With only one cultivar (Immigrant) in the U.S.A. there was a lack of available germplasm to start a breeding program. Part of the interest in new cultivars included development of taller statured plants for improved winter grazing and better game bird and small mammal habitat. Because little variation had been observed in Immigrant for stature and height, scientists at the USDA-ARS-FRRL attempted to obtain seed of Kazakhstan germplasm from the N.I. Vavilov of Plant Industry. As part of a cooperative program between the U.S.A. and Russia, the USDA-ARS International Programs helped fund a forage kochia collection trip to Russia and Kazakhstan.

Collection Expedition Team and Itinerary

The collection team consisted of the six authors of this paper and represented the USDA-ARS, N.I. Vavilov Research Institute of Plant Industry (VIR) (in Russia), and the National Academic Center for Agricultural Research of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

Leg 1 of the expedition consisted of a collection trip to the South of Chelkar, Kazakhstan and East of the Aral Sea prior to the arrival of the U.S. participants. The collection route for leg 2, which included the U.S. participants, was to the Kazakhstan steppe north of Chelkar, Kazakhstan. Leg 3 of the expedition occurred after the departure of the U.S. participants and went southwest of Chelkar (northwest of the Aral Sea). With the exception of a listing of the species collected and sent to the U.S. from leg 1 and 3, all other

In: McArthur, E. Durant; Fairbanks, Daniel J., comps. 2001. Shrubland ecosystem genetics and biodiversity: proceedings; 2000 June 13–15; Provo, UT. Proc. RMRS-P-21. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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details in this paper pertain to leg 2 in which the U.S. participants were present.

The purpose of the collection trip was clearly defined in the beginning as:

- 1. To expand the U.S. germplasm base of forage kochia.
- 2. To make a collection of forage kochia ecotypes which would have the potential to be used in the development of a valuable summer, fall and winter forage.
- 3. To continue to develop contacts and to expand upon interactions for germplasm exchange and related agricultural research with scientists and administrators associated with the N.I. Vavilov Institute of Plant Industry at St. Petersburg, Russia and the Aral Sea Experiment Station for Plant Genetic Resources at Chelkar, Kazakhstan.

While forage kochia was the primary species of interest, additional species were collected that might fit into the same niche as forage kochia.

Itinerary for the Second Leg of Germplasm Collection Expedition

The collection trip occurred in the fall of 1999 with travel dates for the U.S. participants being October 2 to October 28, 1999. Because of logistics only 11 of those days were spent collecting plant materials. The rest of the time was spent in travel, visiting institutions, and preparing the seed for export to the U.S. as outlined below.

Itinerary:

- Travel Logan, UT to Moscow, Russia...Oct. 2-3
- Travel Moscow, Russia to Chelkar, Kazakhstan...Oct 4-6
- Collection-Chelkar, Kazakhstan northward to Karabutak, Kazakhstan; Karabutak southeast to Irghiz, Kazakhstan; Irghiz southwest to Chelkar, Kazakhstan...Oct 7-17
- Collection-Sandy desert south of Chelkar...Oct 19
- Travel Chelkar, Kazakhstan to St. Petersburg, Russia... Oct 20-23
- St. Petersburg, Russia (N.I. Vavilov Research Institute)...Oct 24-27
- Travel St. Petersburg, Russia to Logan, UT...Oct 28

Institutions Visited:

- Aral Sea Experiment Station for Plant Genetic Resources, 27 Biyeckenov Street, Aktyubinsk Region, Chelkar Town, Republic of Kazakhstan, 464760.
- N.I. Vavilov Institute of Plant Industry, 42 Bolshaya Morskaya Street, 190000, St. Petersburg, Russia.

Collection Trip Results and Summary

The expedition was very successful and 246 accessions representing 11 species were collected (table 1). The majority of the accessions, 192, were forage kochia (*Kochia prostrata*). An additional, 88 forage kochia accessions were collected during legs 1 and 3.

Those leading the expedition told us that we were the third U.S. collection team to visit the Aral Sea Experiment Station for Plant Genetic Resources in Chelkar, Kazakhstan. The two previous teams were the Westover-Enlow expedition in 1934 (N.I. Vavilov personally accompanied this expedition) and the Asay-Johnson expedition in 1992 (Asay and others 1992). According to the Kazakhstan and Russian scientists, our expedition route did not overlap with Asay and Johnson's, but unfortunately it was too late in the year to make a broad collection of the grass species in the area. We were also told that we were the first Americans to target forage kochia for germplasm collection.

As experienced by Asay and Johnson in 1992, the Foreign Relations Department (Sergey Alexanian and Sergey Shuvalov) and other staff at VIR in St. Petersburg were extremely cooperative, and did an excellent job of facilitating the expedition. Dr. Nicolai Dzyubenko (Vice director of Science and Head of Forage Crops) and Sergey Shuvalov were primarily responsible for organizing our expedition and accompanying us throughout the trip. Dr. Dzyubenko had been director of the Aral Sea Experiment Station for nine years and was familiar with the collection routes and native vegetation. Mr. Shuvalov was fluent in English and acted as interpreter as well as biologist on the collection expedition. Excellent support was also provided through the Aral Sea Experiment Station of Plant Genetic Resources in Chelkar, which provided facilities and arranged for hiring

Table 1—Species collected during leg 1 of expedition to Kazakhstan in 1999^a.

Species	Number of collections	Species	Number of collections
<i>Kochia prostrata</i>	192	<i>Leymus</i> [<i>Elymus</i>] <i>giganta</i>	2
<i>Krascheninnikovia</i>	13	<i>Elymus angustifolius</i>	7
[<i>Ceratoides</i>] <i>papposa</i>			
<i>Atriplex cana</i>	8	<i>Agropyron fragile</i>	7
<i>Camphorosma lessingii</i>	10	<i>Agropyron desertorum</i>	2
<i>Anabasis salsa</i>	1	<i>Stipa sareptana</i>	1
<i>Medicago falcata</i>	3		

^aIn addition, 88 collections of *Kochia prostrata* from the first and third leg of the expedition were brought to the United States. Additional species collected on the first and third legs were: *Haloxylon ammodendron*—98 collections, *Camphorosma lessingii*—49 collections, and *Salsola orientalis*—92 collections.

vehicles and drivers for the expedition. This experiment station was previously under the direction of VIR, but is now administered through the National Academic Center for Agricultural Research of the Ministry of Science and Higher Education of the Republic of Kazakhstan (NACAR). However, close cooperation between VIR and the experiment station is evident. Aushan Khusainov, director of the Aral Sea Experiment Station for Genetic Resources, provided excellent planning and organizational assistance for the trip. He was directly responsible for the logistics of our travel in Kazakhstan and accompanied us in the field, providing taxonomic expertise on the vegetation.

Asay and Johnson noted severe budget restraints at both VIR and the Aral Sea Experiment Station during their visit in 1992. Funding for these institutes was even less in 1999. The staff at the Aral Sea Experiment Station had been reduced to the Director, Mr. Khusainov, and a few maintenance employees. There were no evaluated experimental plots still in existence. The Vavilov Institute also was operating under severe budget restraints, but fortunately appeared to have stabilized and hopefully can rebuild its staff and research activities during the next decade. A recent grant from USAID had allowed them to modernize their long-term seed storage. With the current budget restraints they were mainly focused on germplasm collection and preservation, and had greatly reduced their germplasm evaluation programs. We visited staff and toured projects at the VIR headquarters in St. Petersburg, Russia. Staff visited included Prof. Victor A. Dragavtsev, Director General of the Institute; Dr. Sergey Alexanian, Head of Foreign Relations; Dr. Alexandr Afonin, Climatology; Dr. Vadim Molodkin, Head of Plant Genetic Resources Long-Term Storage Laboratory; Dr. Tamara Smekalova, Herbarium; Andrew Omelchenko, Chief of Computer-Aided Information Systems; Leonid Malyshev, Senior Scientific Researcher of the Fodder Crops Dept.; and Antone Krylov from the Foreign Relations office.

Environmental and Collection Details for Leg 2

Leg 2 of the collection expedition was conducted to the north of Chelkar. The route went as far north as Karabutak, Kazakhstan (a few miles south of the Russian border) and east to Irghiz, Kazakhstan. To our knowledge, we (Waldron and Harrison) were the first Americans to make plant collections in this area. The area had experienced a drought and many plants appeared to be stunted. Livestock numbers were reported to be $\frac{1}{10}$ those of a decade ago, nevertheless, we found grazing everywhere we went, with concentrated animal numbers around villages.

Forage kochia germplasm was collected at 64 sites. These sites were in the Clay and Sand Deserts which included the Brown Desert Steppe, Light Chestnut Steppe, Degraded Solonetz, and Solonetz (Atlas of Agriculture of the USSR 1960). According to scientists from the N.I. Vavilov Institute of Plant Industry these areas have the highest concentration of forage kochia in the former Soviet Union. Plant associations included: *Agropyron-Stipa-Artemisia*; *Artemisia terrae-albae*; *Artemisia terrae-albae-Krascheninnikovia* (*Ceratoides*); *Artemisia-Salsola-Kochia*; *Atriplex-Anabasis-Artemisia*; *Artemisia-Anabasis*; and *Anabasis*. Soil surface

textures included sands, fine sands, sandy loam, sandy clay loam, silt loam, clay loam, clay, and gravelly and cobbly. Most soils in the Clay Desert had a clay loam or clay subsoil and were saline and alkaline. The Solonetz sites had extremely high concentrations of alkali and salt. The subsoil in the Sandy Desert was mainly sand to fine sand. Elevations ranged from 250 feet near the city of Irghiz to 1000 feet above sea level north of Karabutak. Annual precipitation, averaged over 14 to 43 years, listed Chelkar at 6 to 9 inches, Irghiz at 6 to 8 inches, and Karabutak at 10 to 12 inches (Climate of the U.S.S.R. 1968; Agricultural management in the Aktyubinsk region 1958). Average air and soil surface temperatures at Chelkar are 41.9 °F and 46.4 °F, respectively; at Irghiz 41.5 °F and 44.6 °F, respectively; and at Karabutak 37.3 °F and 41.0 °F, respectively (Climate of the U.S.S.R. 1968).

We made 246 germplasm collections of which 192 were forage kochia. Collections are listed by species in table 1. Species associated with forage kochia included:

Forbs—Yarrow (*Achillea micrantha*), annual chenopod, annual kochia (*Kochia laniflora* and *Kochia scoparia*), knapweed (*Centaurea picris* and other spp.), knotweed (*Polygonum* spp.), buckwheat (*Eriogonum* sp.), fisheye (*Ceratocarpus arenarius*), Russian thistle (*Salsola iberica*), locoweed (*As-tragalus* sp.), and yellow flower alfalfa (*Medicago falcata*);

Shrubs—*Artemisia austriaca*, *Artemisia arenaria*, *Artemisia terrae-albae*, *Salsola orientalis*, winterfat (*Krascheninnikovia* [*Ceratoides*] *ewersmanniana* and *Krascheninnikovia* [*Ceratoides*] *papposa*), saltbush (*Atriplex cana*), camphorosma (*Camphorosma lessingii*), *Anabasis* (*Anabasis salsa*), *Ephreda* spp., and *Haloxylon aphyllum*;

Grasses—Siberian wheatgrass (*Agropyron fragile*), crested wheatgrass (*Agropyron desertorum*), needlegrass (*Stipa sareptana*), giant wildrye (*Leymus* [*Elymus*] *giganta*), spreading wildrye (*Elymus angustifolius*), *Bromus inermis*, *Poa* spp., *Festuca ovina* and other *Festuca* spp., *Stipa capillata*, reedgrass (*Calamagrostis* sp.), redtop (*Agrostis* sp.), orchardgrass (*Dactylis glomerata*), saltgrass (*Distichlis* sp.), tall wheatgrass (*Thinopyrum ponticum*), *Elymus* spp., *Leymus* spp., quackgrass (*Elytrigia repens*), foxtail (*Hordeum* sp.), and junegrass (*Koeleria* sp.).

Forage kochia on average made up 6 percent, ranging from 1 to 20 percent, of the perennial plant composition on native steppe sites where it was present. Percentage composition depended on the site and associated species. For example lower percentages of forage kochia were found on the *Agropyron-Stipa-Artemisia*, *Artemisia terrae-albae*, and *Artemisia-Krascheninnikovia* (*Ceratoides*) sites while higher percentages were found in the *Artemisia-Salsola-Kochia*, and *Atriplex-Anabasis-Artemisia* sites. Overall, *Artemisia terrae-albae* was the dominant species throughout the native steppe area. When it was present, forage kochia made up a higher percentage of the plant composition in disturbed areas, such as along road sides, in abandoned fields, and on farmsteads where a high percent of annuals were present. On these sites forage kochia ranged from 15 to 60 percent, and averaged 32 percent of the plant composition.

As indicated above forage kochia made up a small percentage of the perennial plant communities. Nowhere on the Kazakhstan steppes did we observe forage kochia to be dominant in communities comprised of sagebrush, winterfat,

saltbush, *Anabasis*, crested and siberian wheatgrass, and needlegrass. Instead, forage kochia complimented the biodiversity of such communities. In addition, we did not observe forage kochia invading from disturbed sites into the surrounding perennial plant communities.

The forage kochia germplasm collected was mainly the glabrous and red-green stem forage kochia (*Kochia prostrata* ssp. *virescens*), however, some of the forms were gray with heavy pubescence on the leaves and stems and were classified as ssp. *grisea*. Other forms were in-between the red-green stem and the gray stem subspecies which indicated that the two subspecies may hybridize. This was confirmed by Dr. Dzyubenko and Mr. Khusainov whose combined experience with forage kochia expands over 20 years. Seed was collected by bulking seed from plants with similar morphological characteristics found at the same site. The morphological characteristics included: Height—one to three feet; Seeds—small and large, and few to numerous; Branches or tillers—few to numerous, and basal or high on the stem; Leaves—mostly basal or throughout the stems and branches; stem diameters—fine (about 1/16 inch) or thick stems (about 1/4 inch); stem color—red, yellowish-green, or gray; leaves, branches and stem—glabrous or pubescent.

Dr. Dzyubenko and Mr. Khusainov were not aware of any current forage kochia genetics or breeding programs in Russia or Kazakhstan. Earlier cytogenetics work in the former U.S.S.R. had documented diploid, tetraploid, hexaploid, and octoploid forage kochia types, and naturally occurring aneuploids resulting from hybridization between ploidy levels. In addition, these scientists suggested that the two subspecies of *virescens* and *grisea*, which are frequently recognized in North American literature, are not well defined and in their native habitat readily hybridize with each other resulting in morphological types intermediate between the subspecies. The possibility of inter-ploidy and inter-subspecies hybridization may partially explain the large amount of variation within forage kochia populations at many collection sites.

The use and value of forage kochia in Kazakhstan was discussed among trip participants throughout the trip. Obviously, forage kochia is an important part of the plant composition throughout the northern Kazakhstan steppe and had been heavily to moderately grazed in most of the collection sites. It was often selectively grazed indicating high palatability and/or high nutritional content. The number of grazing animals on the steppe has dropped to 1/10 the number present at the breakup of the Soviet Union. This greatly reduced grazing pressure and allowed us to collect seed even in grazed areas. The numbers of grazing/browsing animals in order of frequency were cattle, sheep and goats, horses, camels, and Saiga (antelope). We observed utilization of forage kochia by cattle, sheep and goats, and horses, and assumed that camels and Saiga were also grazing the forage kochia. We observed large areas of the native steppe that had been mowed and hayed for winter feed. Forage kochia comprised 1 to 20 percent of that feed with *Artemisia terrae-alba* being the major component and *Stipa* sp. and *Agropyron fragile* making up lesser components. Even though

forage kochia made up a low percentage of the overall biomass in the hay, we assumed that its high nutritional value made it an important component in overwintering livestock. We did not observe solid stands of forage kochia or areas where it had been seeded, and in fact we only saw one attempt to improve the steppe by seeding of any improved forage species—a planting of crested wheatgrass. However, Dr. Dzyubenko and Mr. Khusainov told of 20,000 ha of forage kochia that had been planted in southern Kazakhstan. That area was used for grazing sheep in late fall and early spring to flush the ewes and increase the number of live births.

Evaluation of Collected Material

Most of the collected seed cleared quarantine and arrived at the FRRL in mid-December, 1999. Seedlings were started in the greenhouse in cones. Over 8,000 plants, representing most of the forage kochia collections and some of the *Ceratoides* collections were transplanted in late April (2000) at two semi-arid locations in central and northern Utah. Seed of 58 forage kochia entries that were sent by Dr. Dzyubenko from the 3rd leg of the collection trip arrived too late for the 2000 season and will be started and transplanted in 2001.

Ploidy Level of Collected Forage Kochia

Our observations and discussions in Kazakhstan concerning ploidy levels and natural subspecies hybridization prompted us to do a rapid test of ploidy level using flow cytometry. Leaf samples from five plants of each collection were bulked together and analyzed using Immigrant as a standard.

These tests confirmed that we had collected plants of three ploidy levels: 2x, 4x, and 6x. In some instances it appeared that seed from plants of different ploidy levels had been mixed together (for example, we rarely collected seed from only an individual plant). Most surprising was the number of collections sites where two or more ploidy levels were coexisting (table 2). Ecological genetics would suggest that over time one ploidy level should be most fit and eventually displace the other ploidy levels. During the successional phase the different ploidy levels may cross with each other

Table 2—Ploidy level of forage kochia at sites where more than one collection was made.

Number of sites	Ploidy level observed
4	2x only
7	4x only
10	6x only
2	2x and 4x
7	2x and 6x
4	4x and 6x
6	2x, 4x, and 6x

resulting in aneuploidy, however, we saw very little evidence from the flow cytometry analysis to suggest the presence of aneuploids. These results are being verified by the USDA Forest Service Shrub Lab in Provo, UT.

Summary

In summary, 280 collections of forage kochia were made during a collection expedition to the Kazakhstan steppe in October 1999. These collections greatly broaden the forage kochia germplasm available in the U.S. and include three ploidy levels, two subspecies, and diverse morphological types. The collections are being evaluated at the USDA-ARS Forage and Range Research Lab, in Logan, Utah and will be used to develop new forage kochia cultivars for use as fall/winter forage, greenstripping, and range reclamation.

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